FIG. 1

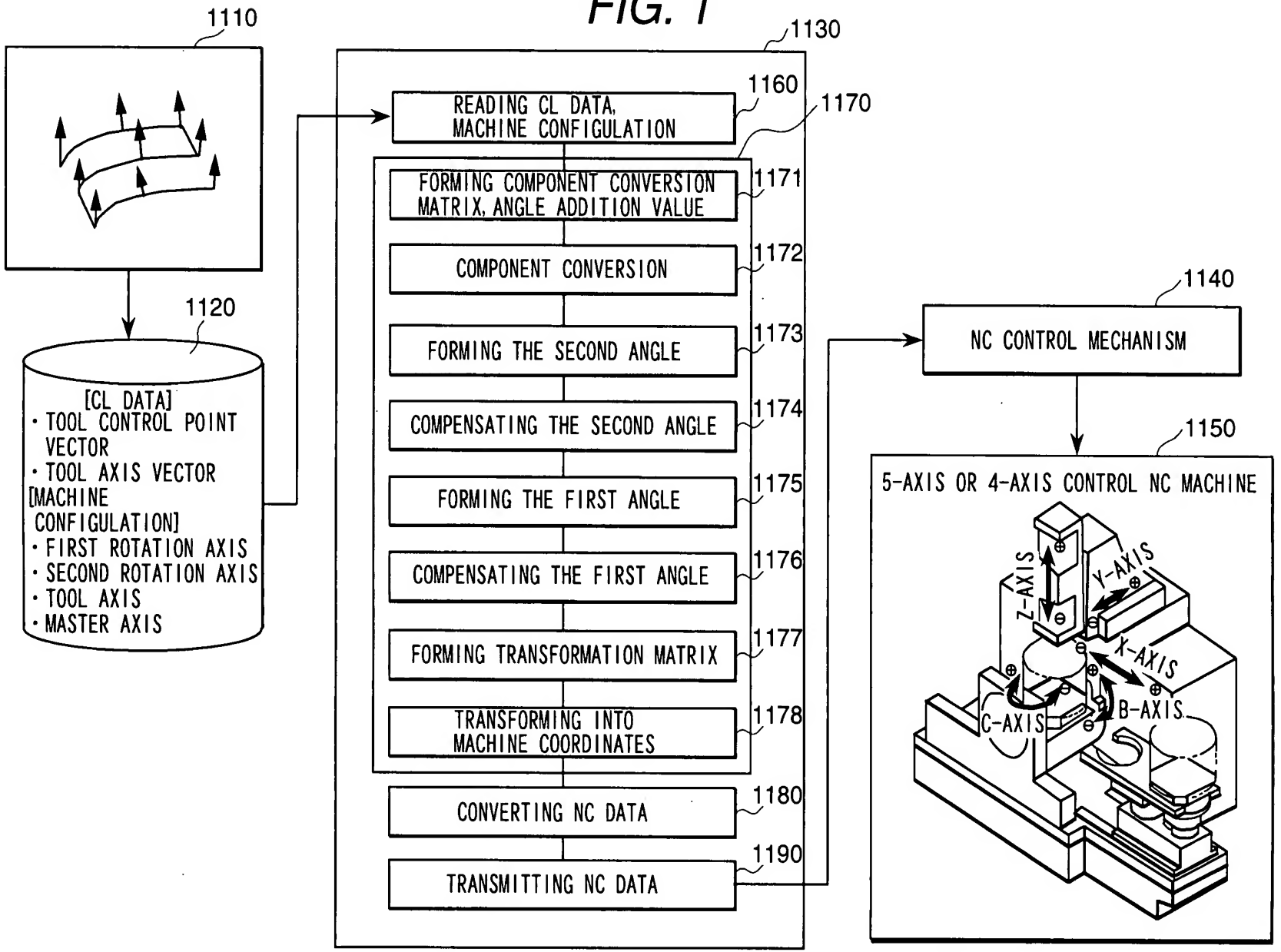

1110
1120
[CL DATA]
• TOOL CONTROL POINT VECTOR
• TOOL AXIS VECTOR
[MACHINE CONFIGULATION]
• FIRST ROTATION AXIS
• SECOND ROTATION AXIS
• TOOL AXIS
• MASTER AXIS
1130
1160
READING CL DATA, MACHINE CONFIGULATION
1170
1171
FORMING COMPONENT CONVERSION MATRIX, ANGLE ADDITION VALUE
1172
COMPONENT CONVERSION
1173
FORMING THE SECOND ANGLE
1174
COMPENSATING THE SECOND ANGLE
1175
FORMING THE FIRST ANGLE
1176
COMPENSATING THE FIRST ANGLE
1177
FORMING TRANSFORMATION MATRIX
1178
TRANSFORMING INTO MACHINE COORDINATES
1180
CONVERTING NC DATA
1190
TRANSMITTING NC DATA
1140
NC CONTROL MECHANISM
1150
5-AXIS OR 4-AXIS CONTROL NC MACHINE
Z-AXIS
Y-AXIS
X-AXIS
C-AXIS
B-AXIS

FIG. 2

MACHINE CONFIGULATION				COMPONENT TRANS-FORMATION MATRIX Ma	AXIS TRANS-FORMATION MATRIX Mc	ANGLE ADDITION VALUE Δ
FIRST ROTATION AXIS	SECOND ROTATION AXIS	TOOL AXIS	MASTER AXIS			
A	C	Z	NOT DESIGNATED	$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	0
B	C	Z	NOT DESIGNATED	$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	0
B	A	X	NOT DESIGNATED	$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	0
A	B	Z	B	$\begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\frac{\pi}{2}$
B	A	Z	A	$\begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$\frac{\pi}{2}$

1210

FIG. 3

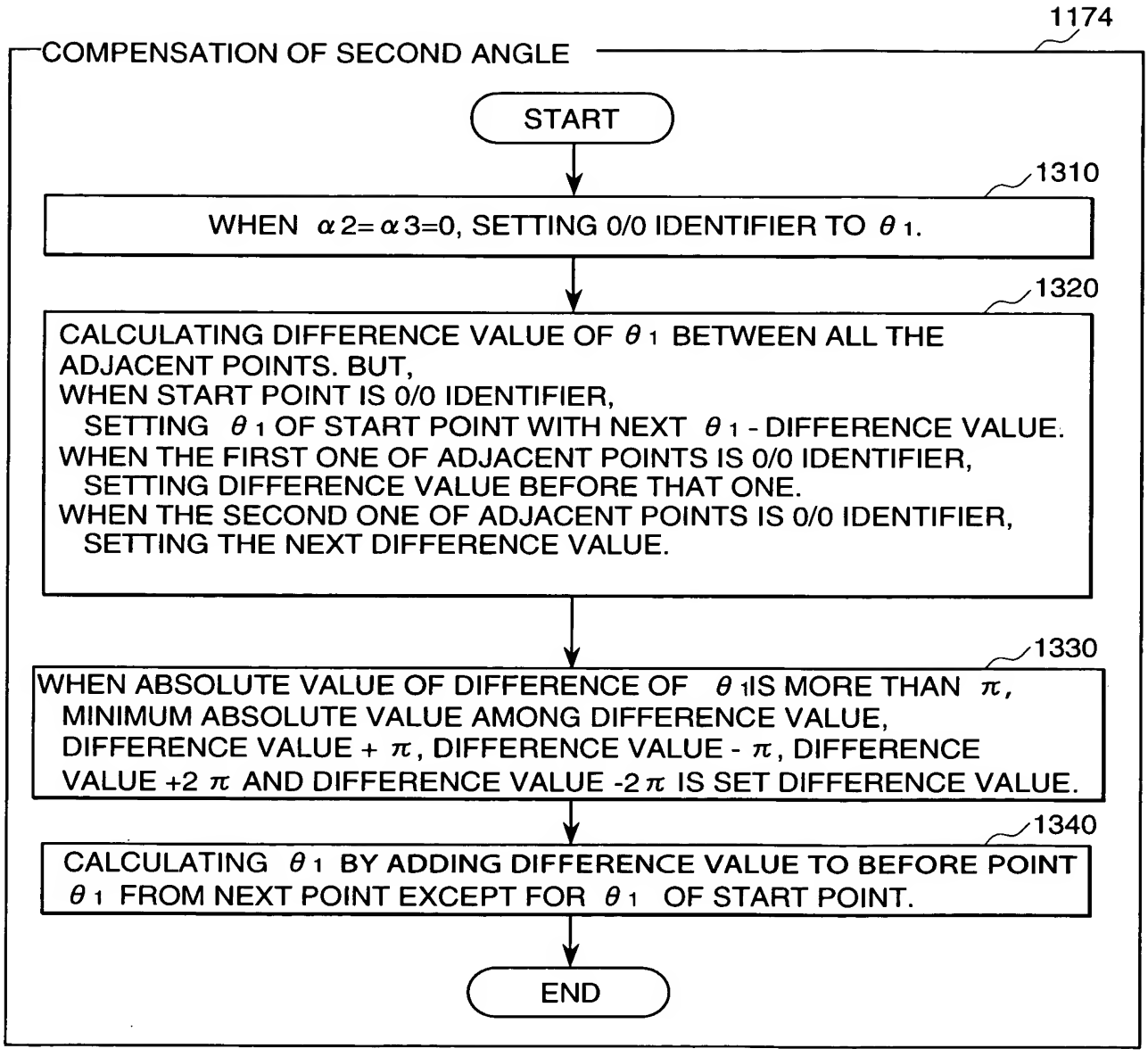

1174
COMPENSATION OF SECOND ANGLE
START
1310
WHEN α2=α3=0, SETTING 0/0 IDENTIFIER TO θ1.
1320
CALCULATING DIFFERENCE VALUE OF θ1 BETWEEN ALL THE ADJACENT POINTS. BUT,
WHEN START POINT IS 0/0 IDENTIFIER,
SETTING θ1 OF START POINT WITH NEXT θ1 - DIFFERENCE VALUE.
WHEN THE FIRST ONE OF ADJACENT POINTS IS 0/0 IDENTIFIER,
SETTING DIFFERENCE VALUE BEFORE THAT ONE.
WHEN THE SECOND ONE OF ADJACENT POINTS IS 0/0 IDENTIFIER,
SETTING THE NEXT DIFFERENCE VALUE.
1330
WHEN ABSOLUTE VALUE OF DIFFERENCE OF θ1IS MORE THAN π,
MINIMUM ABSOLUTE VALUE AMONG DIFFERENCE VALUE,
DIFFERENCE VALUE + π, DIFFERENCE VALUE - π, DIFFERENCE VALUE +2 π AND DIFFERENCE VALUE -2π IS SET DIFFERENCE VALUE.
1340
CALCULATING θ1 BY ADDING DIFFERENCE VALUE TO BEFORE POINT θ1 FROM NEXT POINT EXCEPT FOR θ1 OF START POINT.
END

FIG. 4

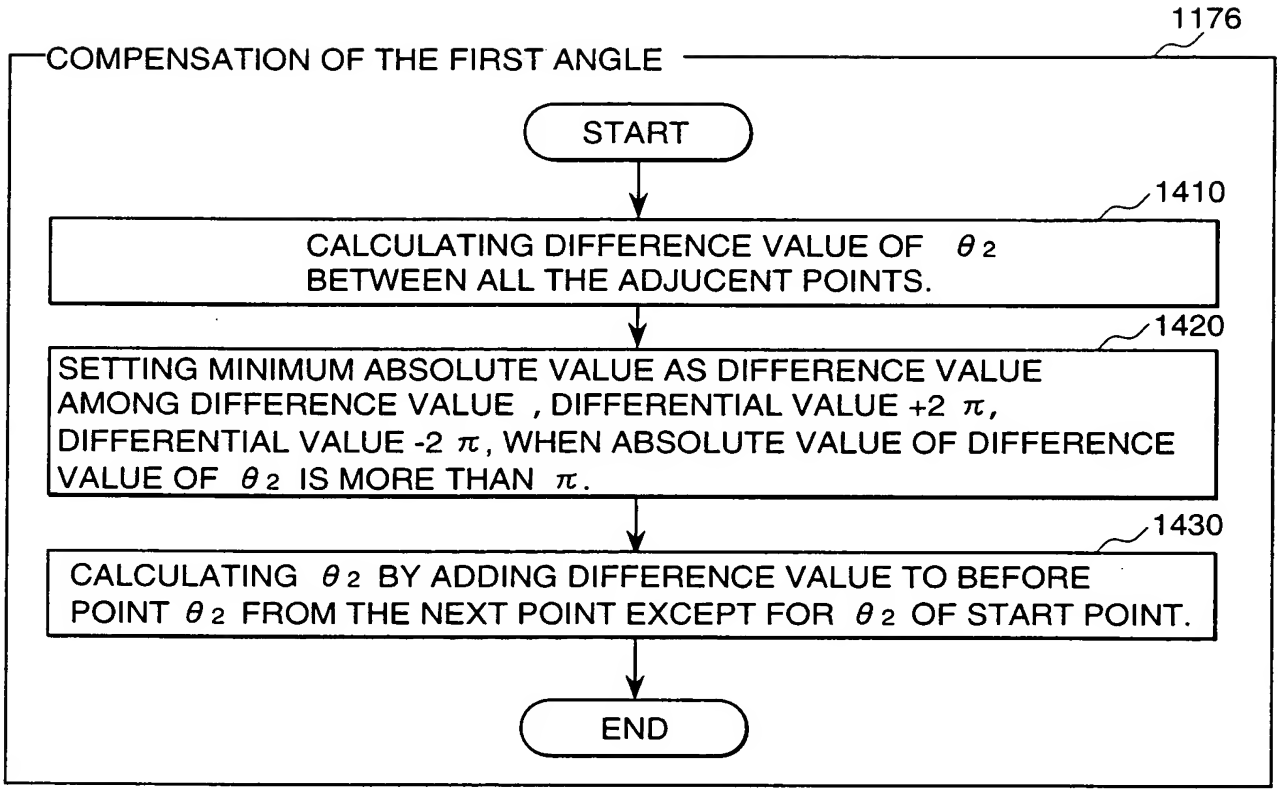

1176
COMPENSATION OF THE FIRST ANGLE
START
1410
CALCULATING DIFFERENCE VALUE OF θ2 BETWEEN ALL THE ADJUCENT POINTS.
1420
SETTING MINIMUM ABSOLUTE VALUE AS DIFFERENCE VALUE AMONG DIFFERENCE VALUE , DIFFERENTIAL VALUE +2 π, DIFFERENTIAL VALUE -2 π, WHEN ABSOLUTE VALUE OF DIFFERENCE VALUE OF θ2 IS MORE THAN π.
1430
CALCULATING θ2 BY ADDING DIFFERENCE VALUE TO BEFORE POINT θ2 FROM THE NEXT POINT EXCEPT FOR θ2 OF START POINT.
END

FIG. 5

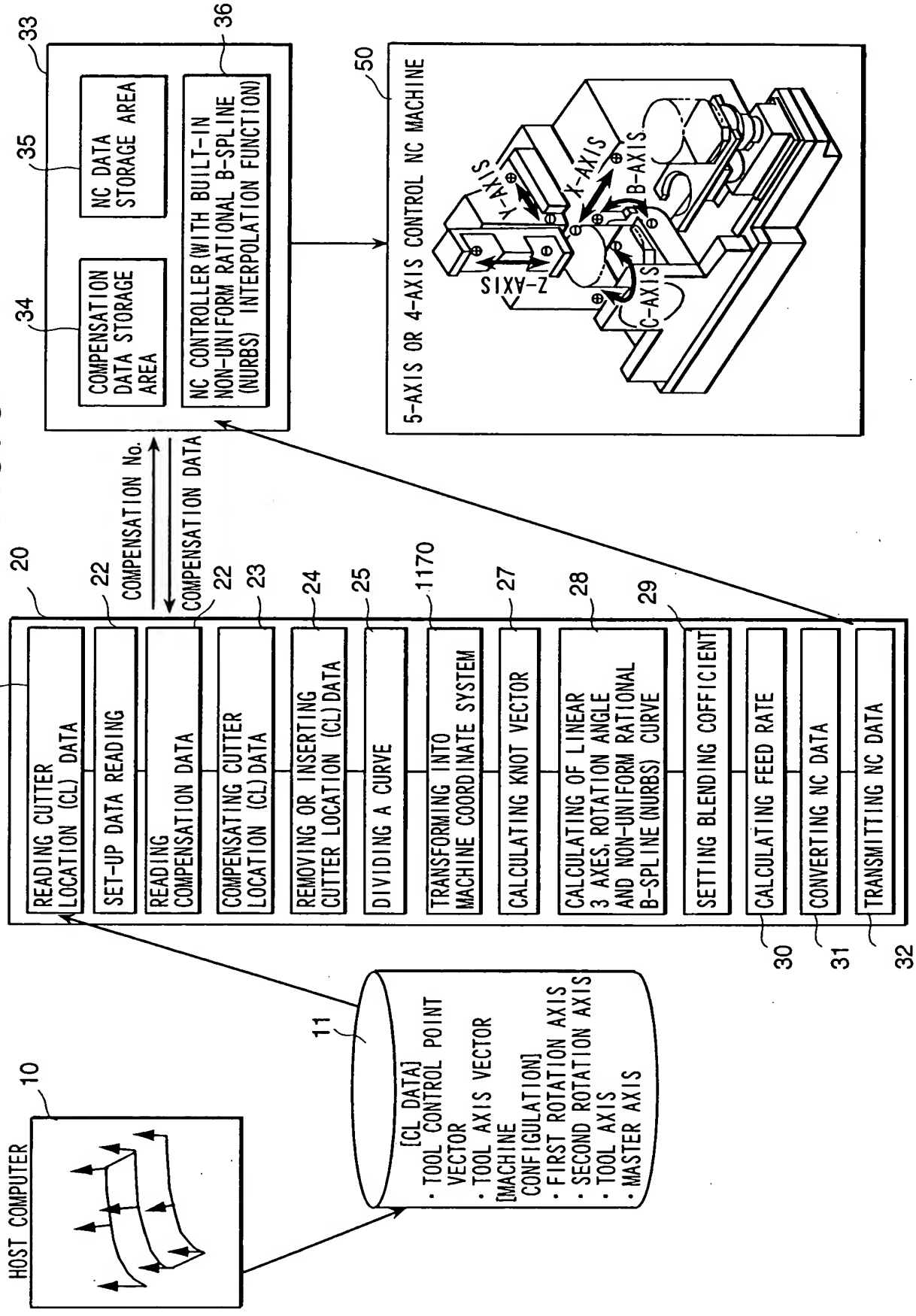

HOST COMPUTER
10
11
[CL DATA]
· TOOL CONTROL POINT
VECTOR
· TOOL AXIS VECTOR
[MACHINE
CONFIGULATION]
· FIRST ROTATION AXIS
· SECOND ROTATION AXIS
· TOOL AXIS
· MASTER AXIS
20
21
READING CUTTER LOCATION (CL) DATA
22
SET-UP DATA READING
COMPENSATION No.
READING COMPENSATION DATA
COMPENSATION DATA
22
23
COMPENSATING CUTTER LOCATION (CL) DATA
24
REMOVING OR INSERTING CUTTER LOCATION (CL) DATA
25
DIVIDING A CURVE
1170
TRANSFORMING INTO MACHINE COORDINATE SYSTEM
27
CALCULATING KNOT VECTOR
28
CALCULATING OF LINEAR 3 AXES, ROTATION ANGLE AND NON-UNIFORM RATIONAL B-SPLINE (NURBS) CURVE
29
SETTING BLENDING COFFICIENT
30
CALCULATING FEED RATE
31
CONVERTING NC DATA
32
TRANSMITTING NC DATA
33
34
COMPENSATION DATA STORAGE AREA
35
NC DATA STORAGE AREA
36
NC CONTROLLER (WITH BUILT-IN NON-UNIFORM RATIONAL B-SPLINE (NURBS) INTERPOLATION FUNCTION)
50
5-AXIS OR 4-AXIS CONTROL NC MACHINE
Y-AXIS
X-AXIS
B-AXIS
Z-AXIS
C-AXIS

FIG. 6

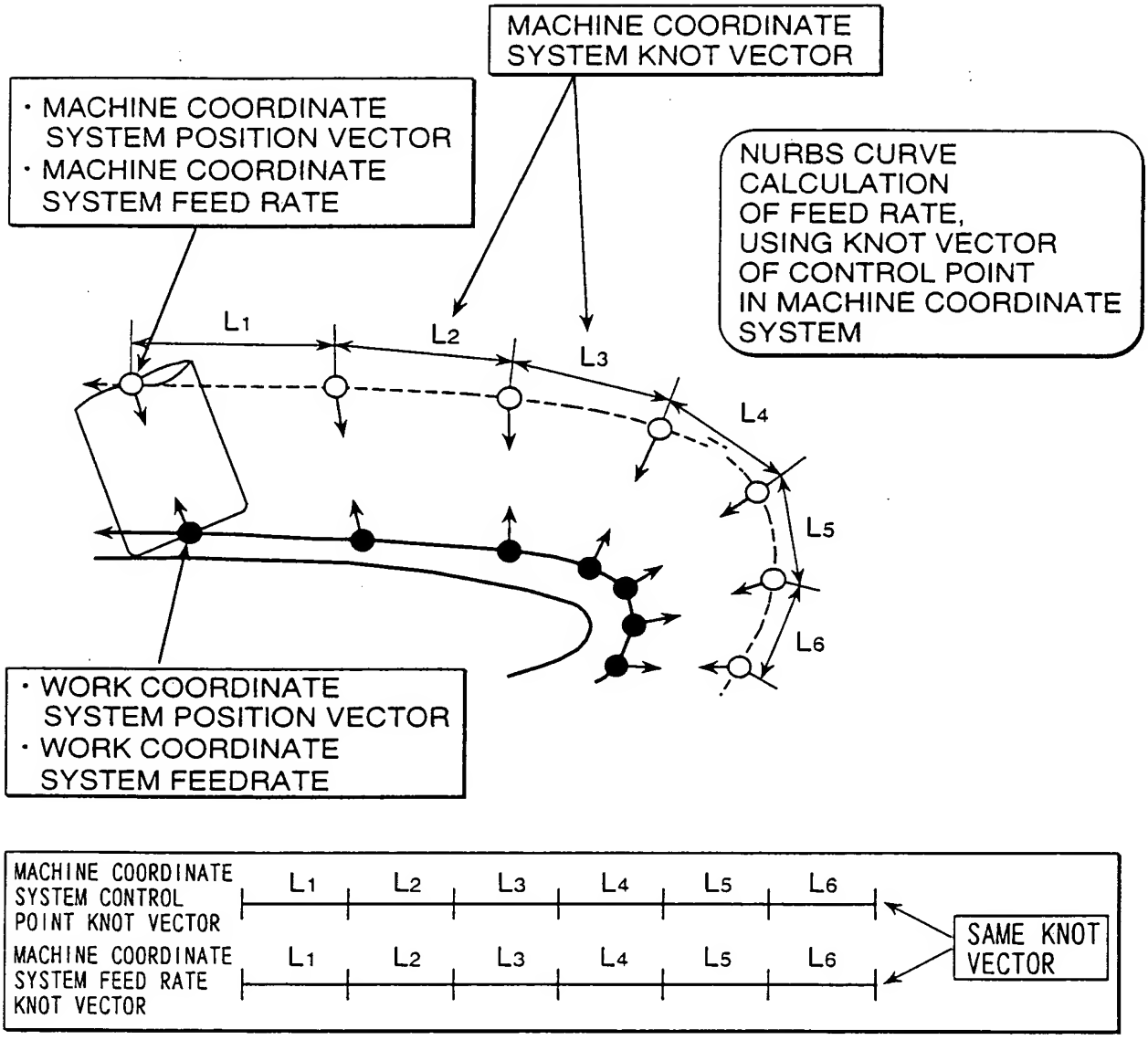
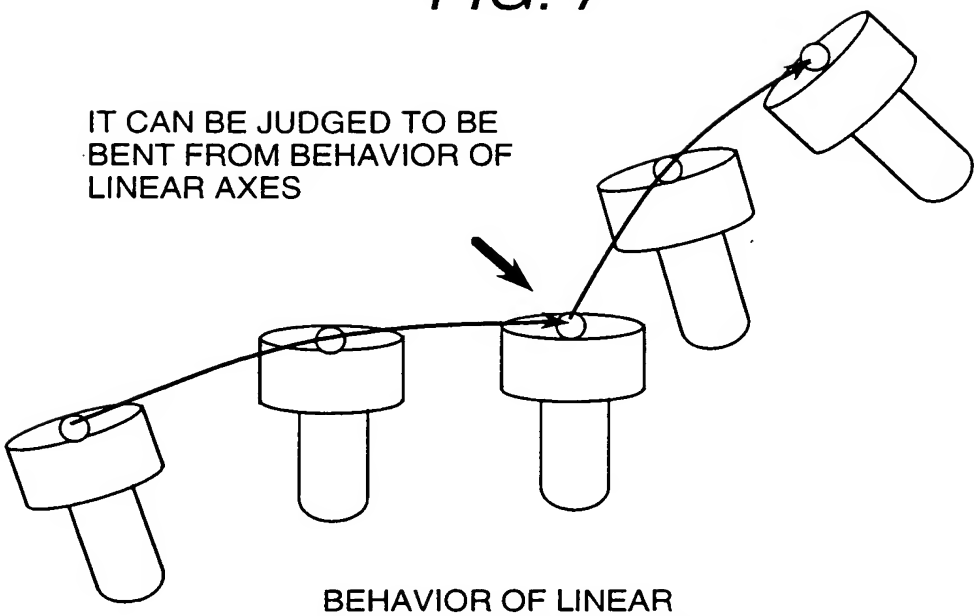
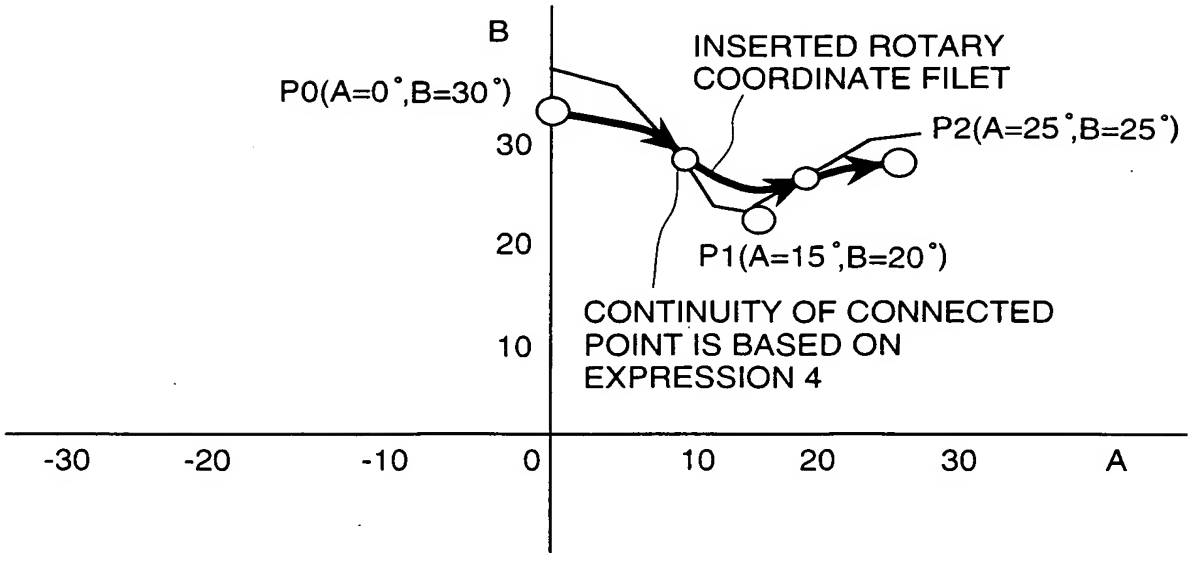

MACHINE COORDINATE SYSTEM KNOT VECTOR
· MACHINE COORDINATE SYSTEM POSITION VECTOR
· MACHINE COORDINATE SYSTEM FEED RATE
NURBS CURVE CALCULATION OF FEED RATE, USING KNOT VECTOR OF CONTROL POINT IN MACHINE COORDINATE SYSTEM
L1
L2
L3
L4
L5
L6
· WORK COORDINATE SYSTEM POSITION VECTOR
· WORK COORDINATE SYSTEM FEEDRATE
MACHINE COORDINATE SYSTEM CONTROL POINT KNOT VECTOR
L1 L2 L3 L4 L5 L6
MACHINE COORDINATE SYSTEM FEED RATE KNOT VECTOR
L1 L2 L3 L4 L5 L6
SAME KNOT VECTOR

FIG. 7



BEHAVIOR OF LINEAR AXES IN MACHINE COORDINATES

FIG. 9



FILET INSERTION IN EXPRESSION BY CONVERSION INTO ROTARY COORDINATE SYSTEM

FIG. 8

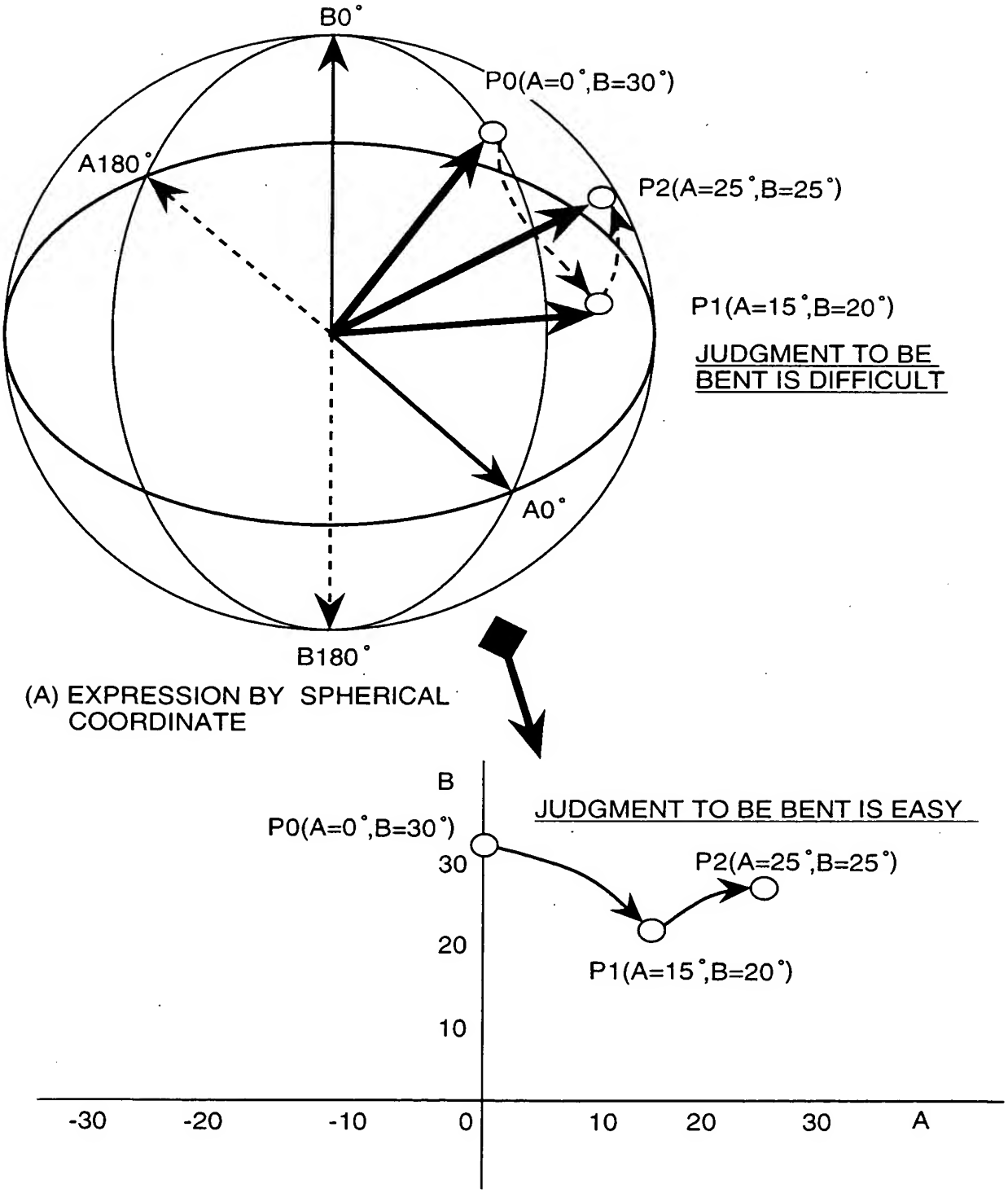

B0°
P0(A=0°,B=30°)
A180°
P2(A=25°,B=25°)
P1(A=15°,B=20°)
JUDGMENT TO BE BENT IS DIFFICULT
A0°
B180°
(A) EXPRESSION BY SPHERICAL COORDINATE
B
JUDGMENT TO BE BENT IS EASY
P0(A=0°,B=30°)
30
P2(A=25°,B=25°)
20
P1(A=15°,B=20°)
10
-30
-20
-10
0
10
20
30
A
(B) EXPRESSION BY ROTARY COORDINATE SYSTEM

FIG. 10

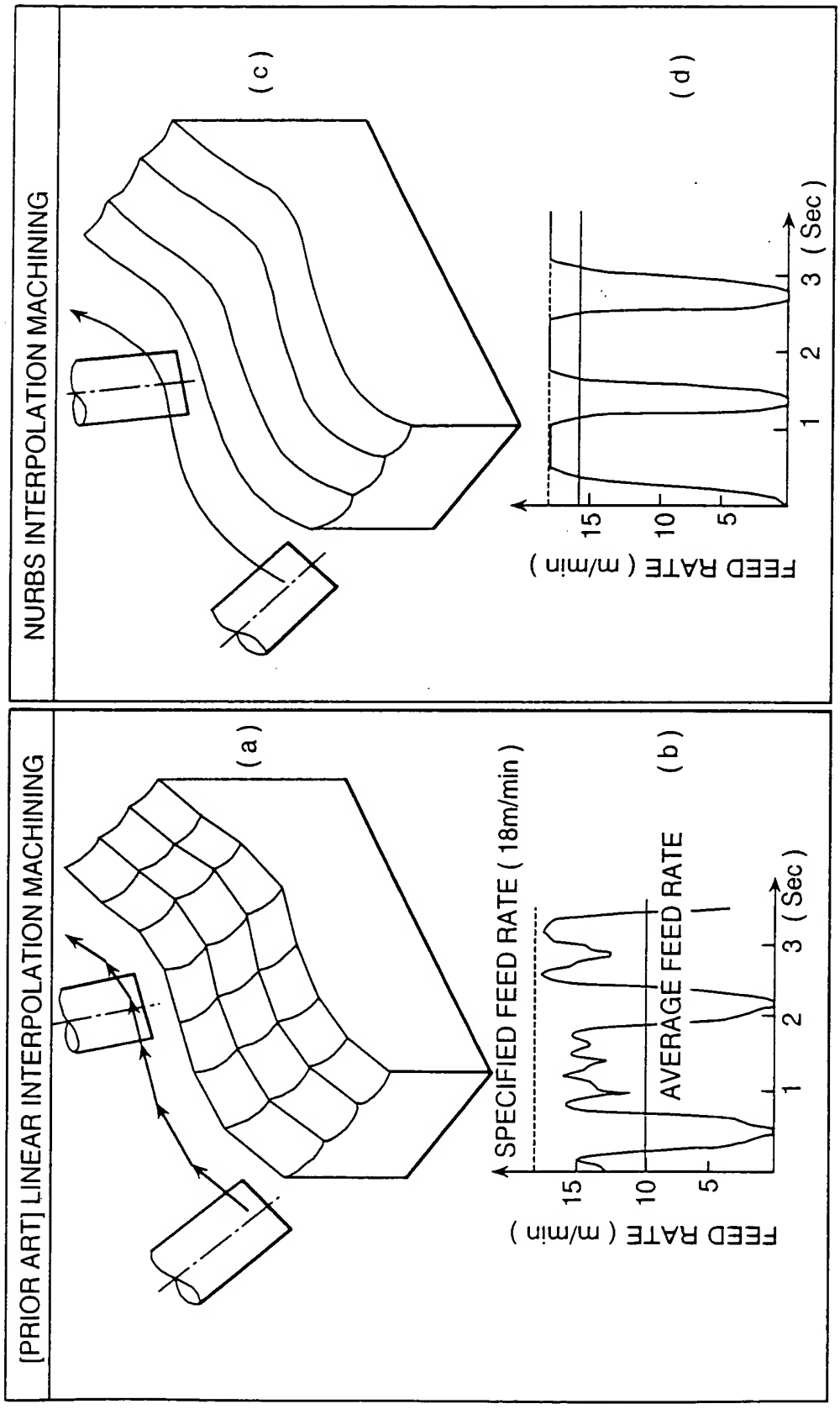
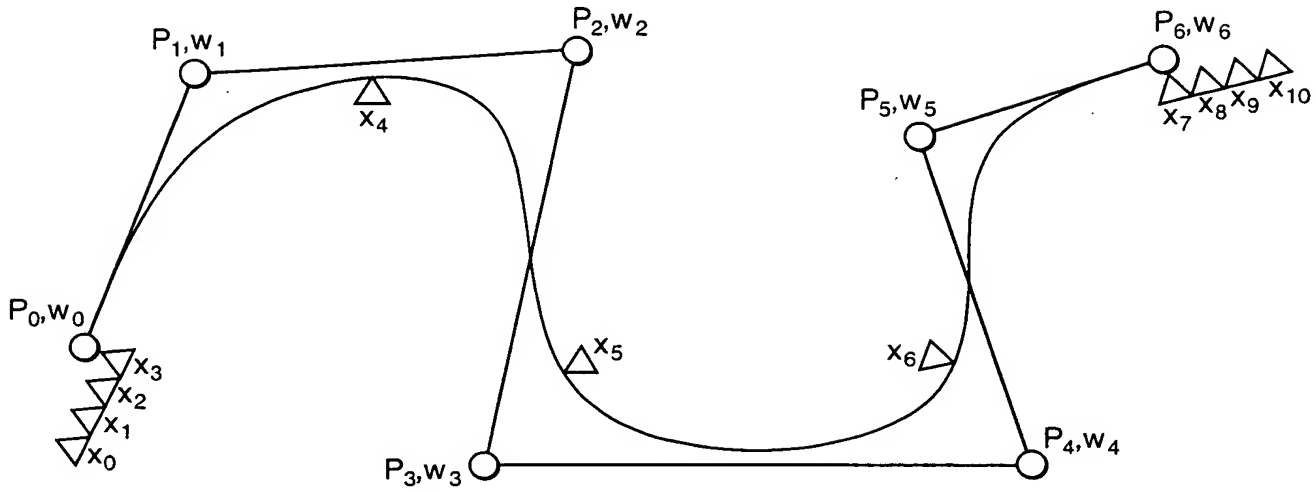

[PRIOR ART] LINEAR INTERPOLATION MACHINING
NURBS INTERPOLATION MACHINING
(a)
(b)
(c)
(d)
SPECIFIED FEED RATE (18m/min)
AVERAGE FEED RATE
FEED RATE (m/min)
15
10
5
1
2
3 (Sec)

FIG. 11



NURBS CURVE FORMED FROM NURBS CONTROL POINTS $P_0 \sim P_n$

FIG. 12

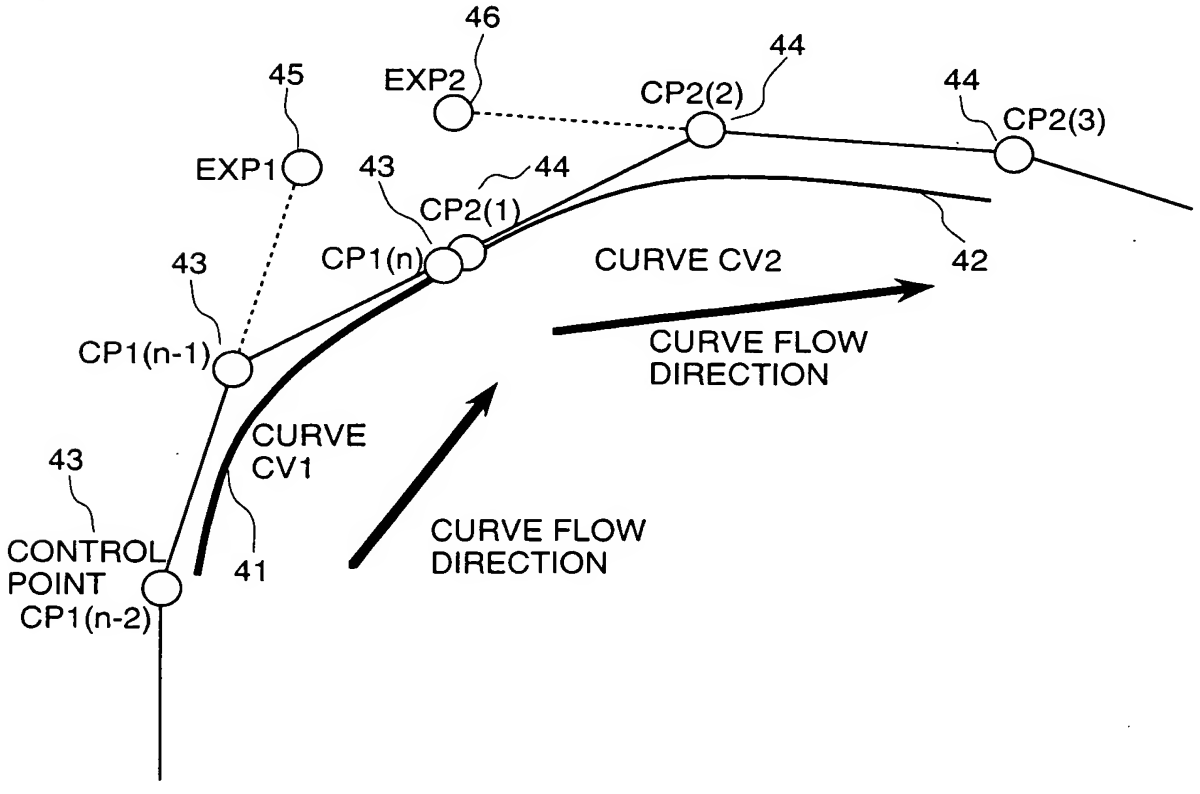
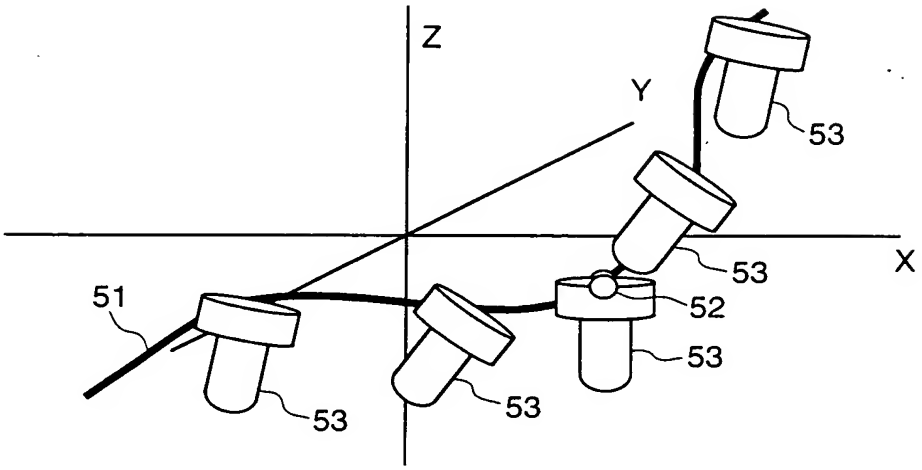
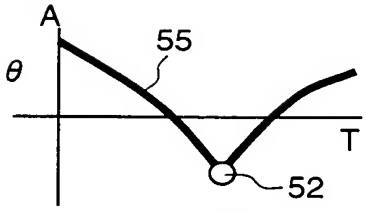


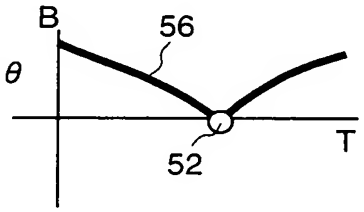
FIG. 13



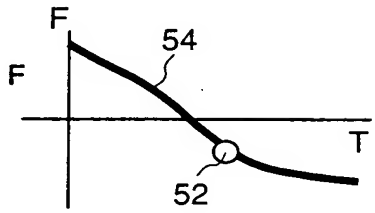
BEHAVIOR OF LINEAR COORDINATE AXES IN MACHINE COORDINATES



A-AXIS

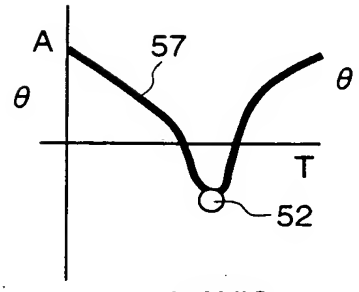


B-AXIS

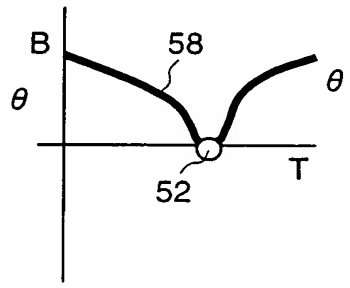


FEED RATE

BEHAVIOR OF ROTARY AXES IN MACHINE COORDINATES



A-AXIS



B-AXIS

BEHAVIOR OF ROTARY AXES IMPROVED IN RAPID CHANGE

FIG. 14

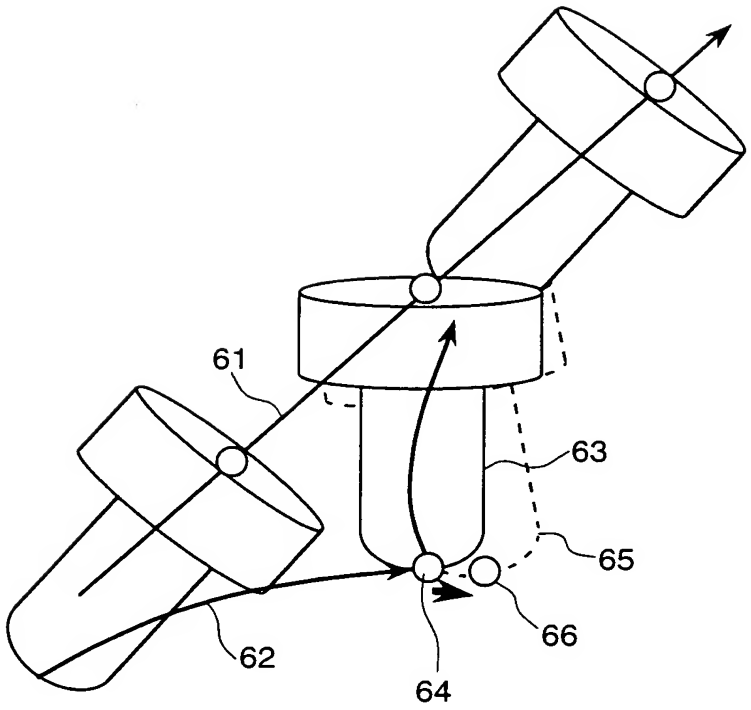


FIG. 15a

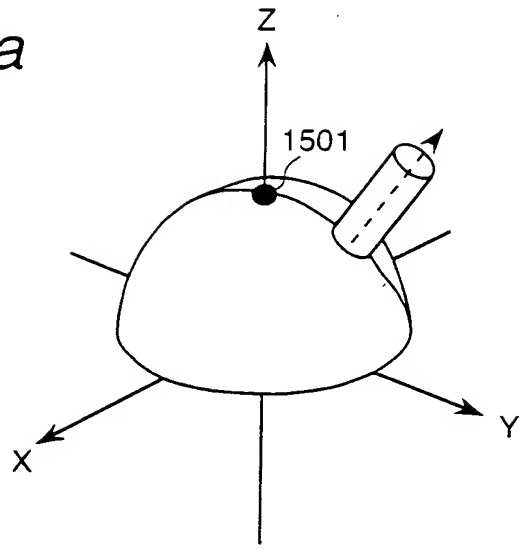


FIG. 15b

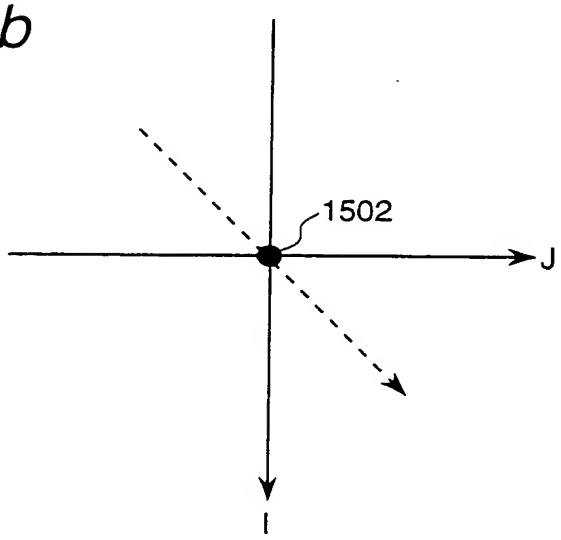


FIG. 15c

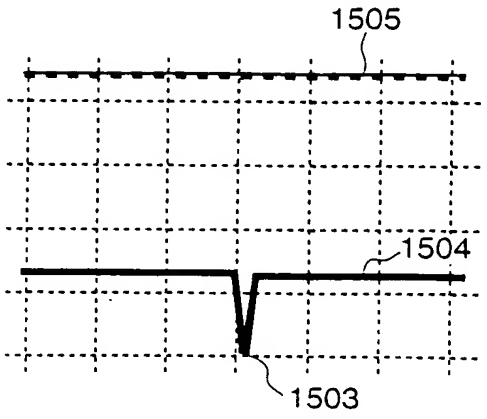


FIG. 16a

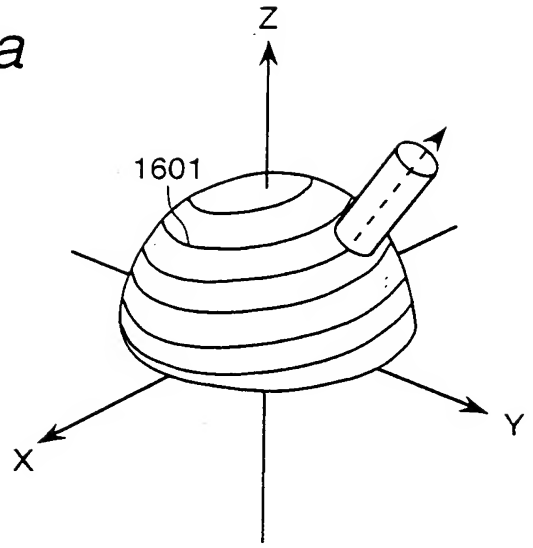


FIG. 16b

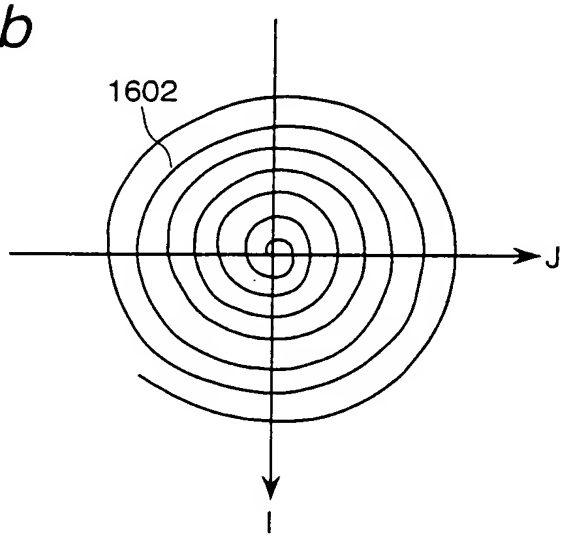


FIG. 16c

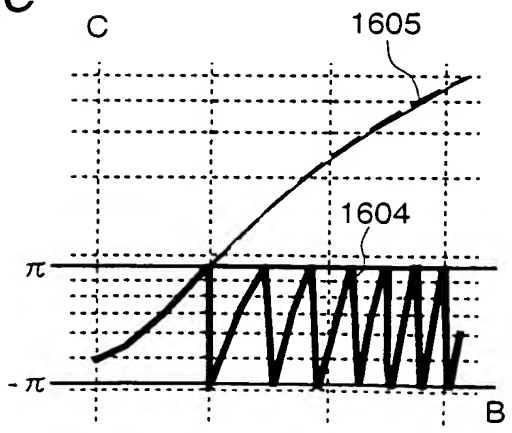


FIG. 17a

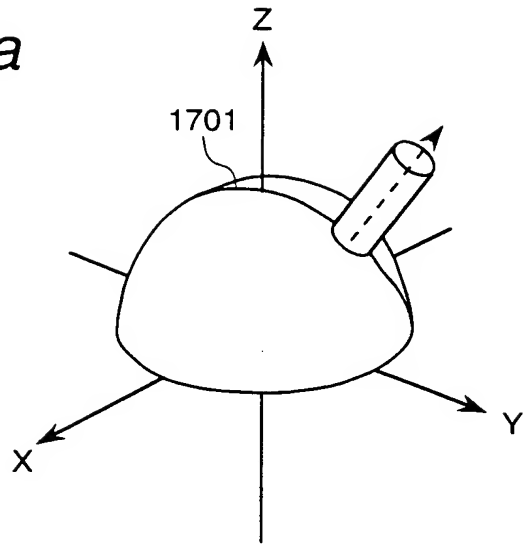


FIG. 17b

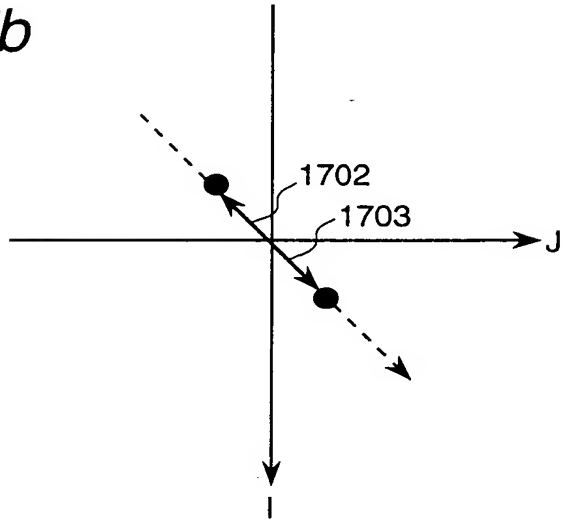
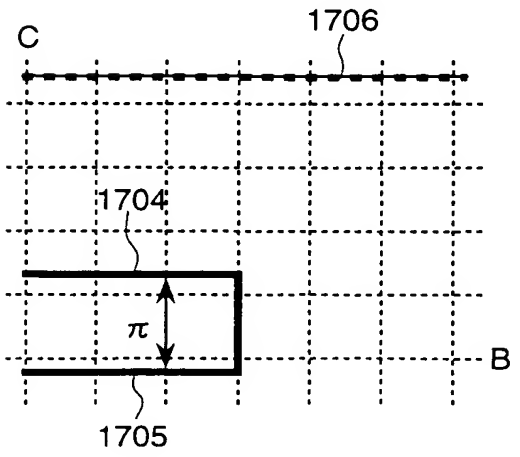



FIG. 17c